Innovative Development of Joining/Fitting Technology for Advanced Composite Piping Systems

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Marshall and the Department of Mechanical Engineering at Louisiana State University (LSU) have teamed up in support of Specialty Plastics, Inc., of Baton Rouge, LA., to develop innovative joining and fitting technologies for advanced composite piping systems. This cutting-edge technology will improve piping systems for the U.S. oil and gas industry.

This new team of industry and university experts and NASA engineers is working to develop high-performance composite materials to dramatically enhance the physical properties—such as strength and durability—of hardware used in the offshore oil and gas industry. One example of the type of composites being used is a combination of polymers with glass or carbon fibers. To date, material costs, along with design and manufacturing complexity, have restricted these types of materials to the manufacture of products for national defense or high-performance sporting goods. However, the cooperative efforts of this team should place high-performance composites into mainstream manufacturing. Specialty Plastics, MSFC, and LSU experts are working to develop joining pipe segments and low-cost, high-strength pipe fittings.

Specialty Plastics has been awarded a $1.8 million Advanced Technology Program grant to help finance research in this high-risk area of technology by the Department of Commerce's National Institute of Standards and Technology (NIST). The company is the first in Louisiana to receive a NIST research and development grant. NIST's Advanced Technology Program provides cost-sharing funding to industries willing to undertake high-risk research and development projects that could spark important, broad-based economic benefits for the United States.

The cost of manufacturing and erecting offshore production platforms can be significantly reduced if even a portion of the heavy metal pipelines could be replaced with lighter weight pipeline systems made of composite materials. Composite pipes could reduce the topside weight of deep-water offshore rigs, known in the industry as tension leg platforms (TLP's). These TLP's are necessary to access deep water petroleum reserves. The replacement composite piping must be developed in such a way that meets the very stringent mechanical requirements and safety concerns for oil operators of sea water piping systems. A large percent of “dead weight” on the deck of an offshore oil platform is the piping system. NIST estimates that the use of composites to access oil from deep water reserves could decrease the cost of deep-water platforms by $250,000/m of water depth, or $150 million per platform by reducing structural weight.

The United States now spends more than $1 billion a week to import oil from other countries. This accounts for half the national trade deficit. A promising source for new oil and gas is from deep-water locations in the Gulf of Mexico. While most offshore production platforms are “fixed” structures based on steel technology, the most economical deep-water platform design includes TLP's. Today, the cost of a TLP is nearly $1.2 billion. For every ton of dead weight saved topside, two tons can be saved below the water line. The weight of steel piping is an important factor in the high costs associated with construction of deep-water platforms. It is essential for Government agencies to be involved in developing the technologies necessary to reduce the capital required for these state-of-the-art TLP's because the costs of developing these deep-water reserves have kept the U.S. oil industry from earning its cost of capital in the past 6 to 7 years. Due to our dependence on hydrocarbons as a primary fuel source for industry and defense, the domestic oil industry is vital to America's economic well-being.

Producing affordable piping made from advanced composite materials will also benefit other U.S. industries. For example, advanced composite piping could have applications for fire water piping, sea water cooling, drainage systems, and sewerage systems without the negative effects of corrosion. Each year, the petrochemical, pulp, paper, and marine industries spend approximately $20 billion to combat corrosion damage to piping made with present-day materials.

Although the benefits of composites—lightweight, corrosion resistant, handling ease, etc.—have long been appreciated, there are technical challenges and barriers to overcome. Some of these challenges and barriers include the lack of confidence in existing joint technology, high costs and intensive labor processes associated with the manufacture of composite pipe fittings, and unreliable composite-to-composite and composite-to-alloy joining methods. The efforts of Specialty Plastics, MSFC, and LSU to develop innovative joining methods will allow advanced composite pipe systems to be considered in essential services, such as fire water systems where copper-nickel pipes are now used. A composite piping system consists of pipe, fittings, joints, and flanges. The limitations of composite piping system applications are due to the joining method and fitting manufacturing process. The current cost of a composite pipe fitting is approximately six times the cost of an alloy fitting.

In order to accomplish their task, this new development team has two distinct tasks—joint technology and fitting manufacturing technology. Where joint technology is concerned, the development of the “integral flange” filament wound directly onto the pipe or fittings eliminates the joint between the pipe and flange and improves the mechanical properties. Another solution involves a heat-activated coupling system which allows the joining of composite pipe to composite and alloy pipes. Improved adhesive bonding must also be a part of this task to ensure a proper bond between adhesives and composites. Fitting manufacturing technology will include processes to improve the overall performance of the piping system. New pipe fitting manufacturing processes will be developed to provide a higher production rate and enhanced properties at a lower unit cost. This task can be accomplished by intelligent filament winding and resin transfer molding of pipe fittings. This is done using two-dimensional woven fabric and three-dimensional shape performs.

New technologies are necessary to improve the reliability of composite components and reduce the cost of manufacturing components such as pipe fittings. These new technologies will ultimately lead to improved joining methods and lower-cost composite pipe fittings, allowing companies to develop suitable alternative products for carbon steel pipes. One of the greatest advantages of composite materials is the flexibility of design. Potential applications for composite pipe on deep-water platforms include process water, cooling water, potable water, nonhazardous waste water, nonhazardous drains and vents, chemical lines, fire water ring main, fire water wet deluge, fire water dry deluge, and ballast water. It has been estimated that composite pipe could be installed for one-fourth the cost of copper-nickel pipe in fire water systems. With lower cost fittings and reliable joining methods, a composite pipe system specifically designed for nonessential services could be installed for approximately the same cost as carbon steel pipe. However, the composite pipe would have an improved life cycle cost and one-fifth the weight of carbon steel pipe. To gain accelerated code acceptance and designer confidence, representatives from Shell Offshore, ARCO, Amoco, American Bureau of Shipping, and the U.S. Coast Guard are serving as collaborators on this project.

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Biographical Sketch: Chris Bramon is a project manager in the Technology Investment Office at NASA-MSFC. He works with industry, academia and other government agencies to develop dual-use technologies that benefit both the public and private sectors. Mr. Bramon has an industrial engineering degree from Iowa State University. He has worked for NASA for 5 years.

Tom Delay is working as a materials/manufacturing engineer in the nonmetallic engineering division of MSFC’s Materials and Processes Laboratory. His work is primarily in the development of launch vehicle hardware and components out of advanced composites. This hardware includes composite tanks for cryogenic applications, composite pipe and duct systems, and composite molds and tooling. He has a degree in physics from Southwestern Oklahoma State University and an M.B.A. from Oklahoma State University. He has worked at NASA for 8 years.